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RECONSTRUCTION OF HV-CONVEX BINARY IMAGES WITH DIAGONAL AND ANTI-DIAGONAL PROJECTIONS USING SIMULATED ANNEALING TECHNIQUE

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ABSTRACT

In discrete tomography, reconstruction of binary images in few directions of projection is an old inverse problem of mathematics. Most of the researcher found approximate solution of binary images in the direction of horizontal and vertical directions. Special case binary images by introducing some constraints on the binary images such as convexity and connectivity improved the reconstruction process. In this paper hv-convex binary images were reconstructed in other form of orthogonal projection i.e. in diagonal and anti-diagonal direction. To get the optimize solution of the diagonal and anti-diagonal projection simulate annealing techniques were implemented. It was found that the reconstruction has been improved from the previous technique. The misclassification of pixel values from the reconstructed and the original were considered as the main parameter for comparison of results.

KEYWORDS: Discrete Tomography, HV-Convex, Diagonal and Anti-diagonal Projections & Reconstruction

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Original Article

INTRODUCTION

Reconstruction of an images is an old inverse problem of mathematics, mainly studied in the tomography. Tomography is known as imaging technique of internal sections of 3-D objects through the use of penetrating X-rays. This techniques is used in CT-Scan, Discrete tomography. It is well known that tomography is referred as the imaging techniques of an objects using X-Rays in various direction of projection [1] Reconstruction which can be defined as to construct an image using its projections. Discrete tomography can be defined as reconstructing of discrete object from its projections. One of the main problem in discrete tomography is to reconstruct a binary matrix from its projections. Projections can be horizontal, vertical, diagonal, antidiagonal or two or three of these. Binary matrix is a matrix which consist of only two values viz 0 and 1.[2] The main problem in discrete tomography while using horizontal-vertical projections is that it reduce the number of projections to at most four–which produces switching component in matrix i.e produces many number of solutions for same set of projections. This problem causes the increase in size of solution's space. The projections like Diagonal and anti-diagonal projections solve this problem. Diagonal and anti-diagonal projections shorten the number of solutions for same set of projections. These projections give more informative image than the image reconstructed using horizontal and vertical projections.

[3] The solution space also can be reduced by using some constraints like convexity, connectivity etc. Some constraints make the problem NP-hard while other constraints use polynomial time reconstruction algorithms. To solve NP-Hard problems meta heuristic algorithm like simulated annealing is very useful.

Simulated annealing algorithm is an optimization algorithm which is derived from the term thermodynamic. It is a meta heuristic and stochastic optimization algorithm. It is based on the concept of annealing in metallurgy. When a metal is heated up and slowly cooled down at some controlled conditions. Using this process the size of crystal increases and defects reduces, thus strength of material increases. When this simulated annealing technique is used for reconstruction using diagonal and antidiagonal projections then it provides more optimal and effective solutions.

In this paper, simulated annealing technique is used to reconstruct hv convex images using diagonal and anti-diagonal projections.hv convex images are those which are both h-convex and v-convex. h-convex matrices are those in which each row consists of contiguous ones and v-convex matrices are those in which each column consist of contiguous ones. So hv-convex matrices are those in which each row and column consist of contiguous ones. Contiguous ones in each row or column can be defined as no zero exist between two ones.

PRELIMINARIES

Binary Image

Consider the two dimensional integer lattice Z^2, called the discrete set, the elements of Z^2 are ordered pairs (i,j) For all i, j € Z. Let X= {(i, j): $1 \leq i \leq m$, $1 \leq j \leq n$, m, n € Z} is a discrete set. The function F: X $\rightarrow$ {0, 1} is the binary image to be reconstructed. The binary image is represented by binary matrix F = $(f\text{ij})_{(mxn)}$, with $f$ij = F(X(i,j)). Binary image consists of only two values 0 and 1. White pixels are represented by 1 and black pixels are represented by value 0..

$$\begin{bmatrix} 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Figure 1: Binary Matrix

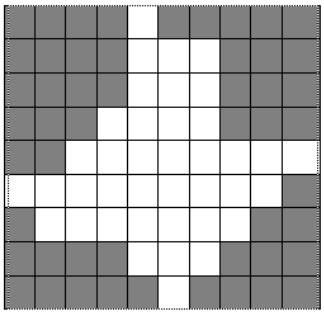

Figure 2: Binary Image

Projections

[4]Let D= {d_1, d_2,……d_{m+n-1}} and A= {a_1,a_2,…..a_{m+n-1}} be two non-integer vectors which represent diagonal and anti-diagonal projections. Diagonal projections are line sums of diagonal elements of matrix and Anti-diagonal projections are line sums of anti-diagonal elements of matrix. H, V lattice lines intersect each other but D, A lattice lines do not intersect each other as shown below.

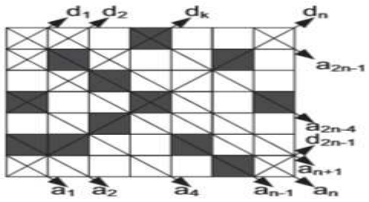

Figure 3: Binary Image Representing Diagonal and Anti-Diagonal Projections

SIMULATED ANNEALING TECHNIQUE

Simulated annealing algorithm is a stochastic optimization algorithm. In general, simulated annealing is a process of annealing in metallurgy in which metal is heated and slowly cooled down to reach at an equilibrium state. An initial solution is required to reconstruct an image using simulated annealing. We use chang's algorithm to get an initial solution from given diagonal and anti-diagonal projections. After computing an initial solution temperature is increased and then gradually decreased to optimize the solution. The optimal solution is achieved by moving from one solution to its neighbour solution. Neighbour solution is the solution obtained by a single switching from its previous solution.. The neighbour solution is accepted if it gives a better objective function value otherwise it is accepted with some probability. The temperature is decreased gradually and at each temperature a fixed number of iterations are performed to attain equilibrium at that temperature. The algorithm is terminated when the temperature reaches a predefined final value. The best solution obtained is given as the output.

Simulated annealing algorithm

Compute initial solution.

Set initial temperature= 1 and iteration counter=0

While (temperature>0.000001 and iterations<1000) do

Randomly choose a switching component.

If ((switching gives a best solution)|| (rand<(old solution-new solution)/temp)) then

Accept the switching, decrease temperature and update iterations.

Else increase the number of iterations

End while

Where 0<rand<1 is a random variable.

IMPLEMENTATION

The implementation is done on proposed algorithm using data sets of images of different sizes of 40x40,50x50,60x60,70x70,80x80,100x100,200x200, 300X300.Each set consists of 60 images and the reconstruction of images using simulated annealing has been compared with that of obtained by Chang[5] algorithms. Further hv convex images [6] using simulated annealing algorithm is compared with Chang's algorithms in percentage of misclassification. Percentage of misclassification can be defined as total difference between Changed pixels divided by total number of pixels.

RESULTS

The results are shown in the *Appendix A*. In the tables images of different sizes are taken. The results show the comparison of original image, image reconstructed using chang's algorithm having diagonal projections, image reconstructed using simulated annealing technique having diagonal projections, image reconstructed using chang's having anti-diagonal and image reconstructed using simulated annealing having antidiagonal projections.

CONCLUSIONS

In this paper simulated annealing approach is applied to reconstruct hv convex images using diagonal and anti-diagonal projections, which gives more optimal and informative solution than horizontal-vertical projections.

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APPENDICES

Tables Representing the Comparison between Chang's Algorithm and Simulated Annealing Technique

Table 1: Comparison between Original and Reconstructed Images of Size 50x50

Size	% of Misclassification	Original Image	Reconstructed Image using Diagonal Projection	Reconstructed Image Having Diagonal Projections using Simulated Annealing Approach	Reconstructed Image using anti-Diagonal Projection	Reconstructed Image Having Anti-Diagonal Projections using Simulated Annealing Approach
50x50						
	<3					
	<4					
	<5					
	<6					
	<7					

Table 2: Comparison between Original and Reconstructed Images of Size 60x60

size	% of Misclassification	Original Image	Reconstructed Image using Diagonal Projection	Reconstructed Image Having Diagonal Projections using Simulated Annealing Approach	Reconstructed Image using Anti-Diagonal Projection	Reconstructed Image Having Anti-Diagonal Projections using Simulated Annealing Approach
60x60	<2					
	<3					
	<4					
	<5					
	<6					
	<7					

Table 3: Comparison between Original and Reconstructed Images of size 70x70

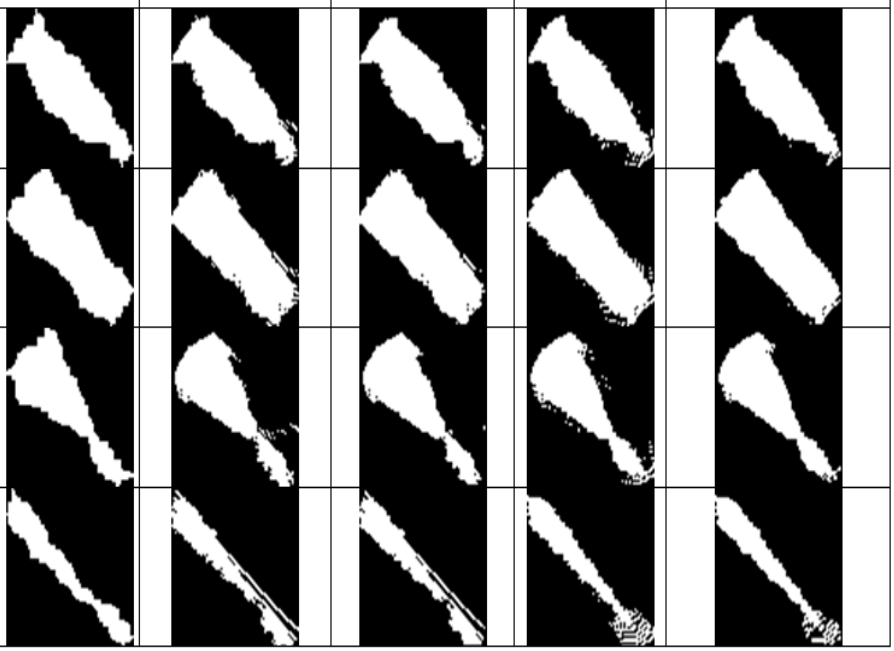
size	% of Misclassification	Original Image	Reconstructed Image Having Diagonal Projections using Chang's Algorithm	Reconstructed Image having Diagonal Projections using Simulated Annealing Approach	Reconstructed Image using Anti-Diagonal Projection	Reconstructed image having Anti-Diagonal Projections using Simulated Annealing Approach
70x70	<2					
	<3					
	<4					
	<5					
	<6					

Table 4: Comparison between Original and Reconstructed Images of Size 80x80

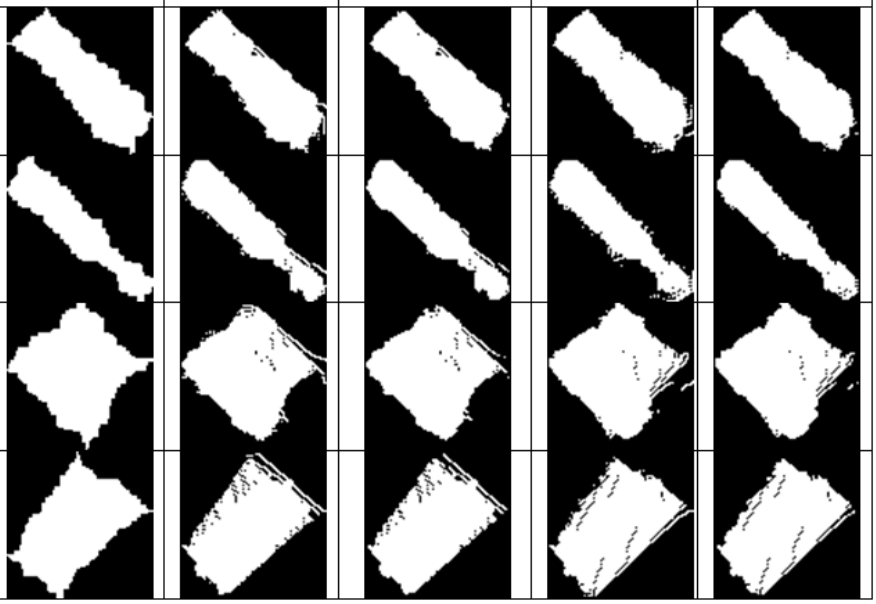
size	% of Misclassification	Original Image	Reconstructed Image using Diagonal Projection	Reconstructed Image Having Diagonal projections using Simulated Annealing Approach	Reconstructed Image using Anti-Diagonal Projection	Reconstructed Image Having Anti-Diagonal Projections using Simulated Annealing Approach
80x80	<2					
	<3					
	<4					
	<5					
	<6					

Table 5: Comparison between Original and Reconstructed Images of Size 90x90

size	% of Misclassification	Original Image	Reconstructed Image using Diagonal Projection	Reconstructed Image having Diagonal Projections using simulated Annealing Approach	Reconstructed Image using Anti-Diagonal Projection	Reconstructed Image Having anti-Diagonal Projections using Simulated Annealing Approach
90x90	<2					
	<3					
	<4					
	<5					
	<6					
	<7					

Table 6: Comparison between Original and Reconstructed Images of Size 100x100

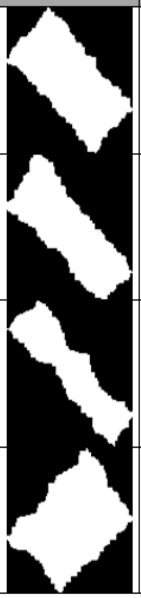
Size	% of Misclassification	Original Image	Reconstructed Image using Diagonal Projection	Reconstructed Image Having Diagonal Projections using Simulated Annealing Approach	Reconstructed Image using Anti-Diagonal Projection	Reconstructed Image Having Anti-Diagonal Projections using Simulated Annealing Approach
100x100	<2					
	<3					
	<4					
	<5					
	<6					

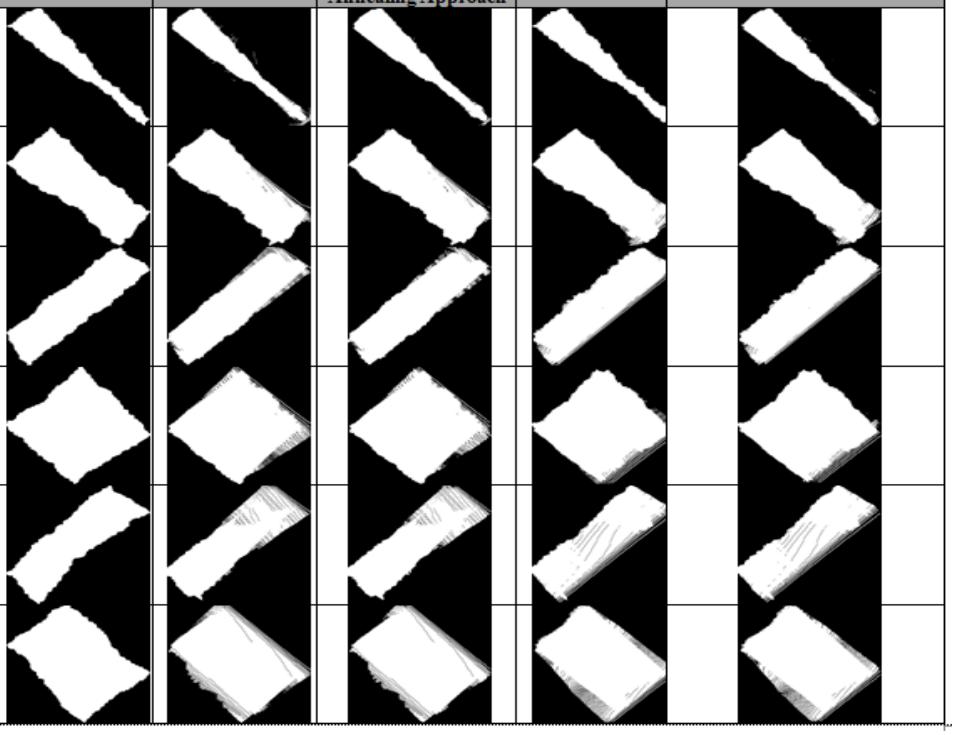
Table 7: Comparison between Original and Reconstructed Images of Size 150x150

Size	% of Misclassification	Original Image	Reconstructed Image using Diagonal Projection	Reconstructed Image Having Diagonal Projections using Simulated Annealing Approach	Reconstructed Image Using Anti-Diagonal Projection	Reconstructed Image Having Anti-Diagonal Projections using Simulated Annealing Approach
150x 150	<2					
	<3					
	<4					
	<5					
	<6					
	<7					

Table 8: Comparison between Original and Reconstructed Images of Size 200x200

Size	% of Misclassification	Original Image	Reconstructed Image using Diagonal Projection	Reconstructed Image Having Diagonal Projections using Simulated Annealing Approach	Reconstructed Image using Anti-Diagonal Projection	Reconstructed Image Having Anti-Diagonal Projections using Simulated Annealing Approach
200x 200	<2					
	<3					
	<4					
	<5					
	<6					
	<7					

Table 9: Comparison between Original and Reconstructed Images of Size 250x250

Size	% of Misclassification	Original Image	Reconstructed Image using Diagonal Projection	Reconstructed Image Having Diagonal projections using Simulated Annealing Approach	Reconstructed Image using Anti-Diagonal Projection	Reconstructed Image Having Anti-Diagonalprojections using Simulatedannealing Approach
250x250	<2					
	<3					
	<4					
	<5					
	<6					
	<7					